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The biofeedback correction of unsteady and eccentric fixation in amblyopia associated with strabismus and anisometropia

Abstract

The biofeedback correction of unsteady and eccentric fixation in amblyopia associated with strabismus and anisometropia

Degree Type

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Master of Science in Vision Science

Committee Chair

Clifton M. Schor

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Optometry

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*The Biofeedback Correction of Unsteady and Eccentric
Fixation in Amblyopia Associated with Strabismus and Anisometropia*

A Thesis

*In Partial Fulfillment of Requirements for the Degree
Doctor of Optometry*

42473

*Presented to
The Faculty of the College of Optometry
of
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March 1977

*by
William Richard Hallmark*

Advisor: Clifton M. Schon, O.D., Ph.D.

Clifton Schon

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The Biofeedback Correction of Unsteady and Eccentric Fixation in Amblyopia Associated with Strabismus and Anisometropia

Introduction

People with amblyopia are often afflicted with abnormal fixation control of their amblyopic eyes; people with normal binocular vision receive visual feedback to confirm or correct eye position to the eye's aim intent. If a visual system develops abnormally, a lack of sensory feedback may occur, thereby contributing to oculomotor anomalies. Of specific interest to us are the anomalies of unsteady fixation and eccentric fixation in amblyopia associated with strabismus and anisometropia. Since a lack of visual feedback appears to be the cause of monocular fixation errors and of fixation unsteadiness, it occurred to us that an alternative form of biofeedback might be of use in their correction.

The classical usage of auditory feedback is associated with Bangerter who has used it in several forms to signal errors in visually guided tracing.⁽¹⁾ More recently, verbal auditory feedback has been used in normal subjects to control the direction, magnitude, and occurrence of fixation saccades.⁽²⁾

Characteristics of Eccentric Fixation

The normal eye, upon attempted steady fixation, is known to have three distinct kinds of movement. First, micronystagmoid movements are constantly

taking place at the rate of about 85 per second. These movements have an extent of about 10" of arc. The second kind of movement is the slow drift, which occurs in random directions. Small, periodic, rapid saccades are the third type of eye movement found in the normal eye. These saccades occur about every second and have an extent of about 5' of arc. (1)

The amblyopic eye, upon attempted steady fixation, has the three kinds of movements described above, but these movements are greatly exaggerated. (1,3,4) It has been found that fixation steadiness is greater if the fovea is used for fixation. If a nonfoveal site is used to fixate, then the smaller the area of this site, the steadier the fixation. Unsteadiness increases when the fixation site is variable. Since anisometropic amblyopes usually have central fixation, they tend to have more stable fixation than squinting amblyopes. (1,5)

Dark adapted amblyopes behave essentially as normals in terms of their eye movements upon attempted steady fixation. (1,4)

Using the foveal center as a point of reference for measuring the angle of eccentric fixation, steadiness of fixation has been found to increase as the angle gets smaller. As this happens, visual acuity is also found to improve. (6) Flom devised a formula to determine visual acuity at an eccentric retinal site, and the formula is used to approximate acuities in amblyopic eccentric fixations. The formula is: $MAR = EF + 1$ (1)

MAR = minimum angle of resolution in minutes of arc

EF = eccentric fixation in prism diopters

Current Methods of Treatment

Accepted treatment regimes include either direct or inverse occlusion concurrently with training. Bangenter's pleoptics methods depress eccentric retinal loci so that fixation will be more favorable with the fovea. Lights within the visual field are then flashed on and off to increase foveal transmission. When the peripheral retina is desensitized, the center of the after-image scotoma is "aimed" in monocular fixation drills. (1)

Bangenter's Localizer, a box having illuminated holes, uses tactile feedback to establish centric fixation and to correct spacial localization. The patient points at and touches the illuminated holes. Bangenter's Connector consists of mazes of various complexity over which the patient traces out the "path" with a metal hand held stylus. If the patient moves off the "path," an electrical circuit is completed to then provide auditory feedback. Another training device, The Drill, is designed to train hand-eye coordination and spacial localization. The patient's task is to place a metal rod into the center of a tube. If a poor placement is made, and the rod touches the side of the tube, a buzzer sounds to signal the error. (1)

Another Bangenter device is called the Vibrating Localizer; it uses auditory, tactical, as well as visual clues for localization. The device is held behind a translucent screen; the sound and vibration of the device are required for localization. After correct localization from the tactile and auditory clues, illumination replaces the sound and vibration as feedback.

The Acoustic Localizer also provides tactile, visual and auditory feedback for correct spatial localization and hand-eye coordination. With this device, the patient places a stylus into an illuminated hole. Tactile feedback is provided by a magnetic field that attracts the stylus. Auditory feedback occurs as the hole is approached and contacted by the stylus. (1)

Cüppers' method provides visual feedback to correct position errors.

The fovea of the amblyopic eye is tagged either with an afterimage or with Haidinger's brushes, and the patient's task is to then aim the tagged fovea at a target. (1)

The possible improvements to anomalous fixation by these and other means of biofeedback are the correction of position error and the correction of high amplitude micro saccades.

Methods

Our experimental objective is to measure and record micro saccadic eye movements of normal and amblyopic eyes under monocular viewing conditions. The subject's fixation instructions are modified periodically throughout the experiment; measurements of saccadic amplitude and frequency, and measurements of drift direction and duration are made both with and without biofeedback. Changes in these features are evaluated in terms of the instructions (i.e. visual task-demand), and in terms of the biofeedback provided or withheld. The types of biofeedback used are both auditory and visual. The visual biofeedback is provided by a Haidinger's brushes device, which gives a signal for aim position error. The auditory device obtains its

signal from an eye movement monitor; it is possible to obtain either a position error signal from the auditory signal generator, or a burst of sound each time a saccade is made. Both visual and auditory biofeedback may be given to a subject simultaneously. In this study, the innate fixation patterns after correction for the micro saccades are found for both normal and amblyopic subjects.

Experimental Design and the Apparatus

Drift and saccadic fixation qualities will be examined under the instructional preset for fixation. The fixational qualities are also examined in the presence of biofeedback with the biofeedback being the only variable. Any differences in the fixational features then only reflect the influence of the biofeedback.

Parts of the apparatus are as follows:

1. The Eye Movement Monitor

The eye movement monitor is a Biometrics SGVH-2 Infrared Eye Movement Monitor. It records the eye position of the fixing eye while the subject performs various fixation tasks.

2. The Recorder

The resultant eye positions are recorded on a strip chart recorder (Honeywell Visicorder), and the results are analyzed in terms of amplitude, and frequency of saccades, and in terms of drift velocity and direction.

3. The Differentiator and Auditory Signal Generator

During the task of biofeedback, the voltage analogue of the derivative of the eye movements drives twin speakers so that bursts of sound are emitted by the left speaker during leftward saccades and by the right speaker during rightward saccades. The pitch of the burst is related to the magnitude of the saccades. The subjects sat between the two speakers with the left speaker on the left and the right speaker on the right such that the direction of the sound corresponded to the direction of the eye movements.

4. The Visual Stimulus

A. The subjects fixated a target consisting of a "plus" constructed of 1/8 inch wide black "Chart Pack" tape. The dimensions of the "plus" are three inches by five inches, and the tape is mounted on a three inch by five inch white index card. A small fluorescent dot covers the intersection of the two lengths of black tape. The target was placed 34 inches from the subjects' eyes.

B. The subjects were instructed to fixate a small spot on the screen of the Haidinger's brushes device so as to place the center of the moving propeller on the spot.

5. The Dental Acrylic Bite Board

A dental acrylic bite board was used to provide stability for the subjects' head positions, thereby greatly eliminating the introduction of noise into the measurements.

The following information is offered concerning the experimental subjects:

1. The Source

Our subject source is the Pacific University College of Optometry student and clinical populations.

2. Subject Characteristics.

Five of the subjects are either anisometropic or strabismic amblyopes having fixation tremor and possibly eccentric fixation. One subject has normal acuity, and no strabismus or anisometropia.

3. Subject Release Forms

The proper release forms have been obtained for each subject.

4. Instructions to the Subjects

During the experiment, recordings of eye movements are made under each of the following instructional presets:

A. The subject is instructed: "Look at the target."

B. While providing saccadic feedback, the subject was instructed to suppress the production of the feedback's rapid fire, high pitched squeal. He was instructed that each of these fleeting sounds reflects a micro saccade, and that he has voluntary control over them. The subject was told not to be concerned if he found his eye drifting off target. The subject was told: "Just let it go ahead and drift. Don't make an attempt to look back at the intersection of the two black lines. Be rather oblivious to the presence of the target."

C. In the cases in which auditory position biofeedback was provided, the subject was instructed to move his eye from side to side until he found a position where sounds from both speakers were at an equally low tone.

D. When auditory saccadic biofeedback and visual position biofeedback were given, the subject was asked first to stop making saccades; he was then asked to try and control his drift to the extent that he align the fixation point with the center of the propeller on the Haidinger's brushes device.

Discussion

A problem which exists when using an audio signal for position error correction is that the signal and therefore the null (i.e. on target) position may be changed simply by changing the palpebral fissure size. This is especially true of subjects with narrow fissures. Consequently this method of position error correction was abandoned in favor of Haidinger's brushes. An additional advantage of using Haidinger's brushes is that correction for both fixation position errors and fixation tremor may be given simultaneously. It is important to note that the problem of changing fissure size does not exist when the eye movement signal is passed through the differentiator.

Results

On the following pages are examples of the subjects' eye position records. In all cases the tracings were calibrated by having the subject look alternately from one point to another on the target. The gain on the eye movement monitor was adjusted to a convenient level. For subjects B.K., M.O., G.W., and K.S. the scale is approximately equal. For subject B.G. the scale is decreased by a factor of approximately 2.5; for normal subject S.H. the scale is increased by a factor of approximately 2.0. Additionally, the time scale for subject S.H. is compressed for some segments shown. All segments for all subjects cover a time span of 10 seconds.

In general, the eye movements shown were the ones used to calculate the results found in the accompanying tables. These segments were chosen as the best 10 second element illustrating minimum saccadic frequency and amplitude, and minimum drift rate. In the case of one subject, G.W., two fixation segments are shown, the one being more illustrative of drifts to the extent that measurements could be made; the other tracing gave smaller readings for saccades. Numerical evaluations are given for each saccadic test done. This was not possible for the drifts in many cases because the duration and directions were so variable. A qualitative evaluation of the drift characteristics is given for the cases in which a numerical evaluation was not possible.

SUBJECT	AMBLYOPIC STEADY FIXATION		AUDITORY SACCADIC BIOFEEDBACK		AUDITORY POSITION BIOFEEDBACK		VISUAL POSITION BIOFEEDBACK		AUDITORY SACCADIC AND VISUAL POSITION BIOFEEDBACK		PERSISTENCE	
	AMP	RATE	AMP	RATE	AMP	RATE	AMP	RATE	AMP	RATE	AMP	RATE
G.W.	0.74	2.0	0	0	0.65	0.5	0	0	0.67	0.1	0	0
R.K.	0.68	1.3	1.18	1.1	1.32	1.1	0.77	1.4	NOT DONE		1.09	0.9
M.O.	0.72	2.3	0.66	0.3	NOT DONE		0.29	0.4	0.27	0.8	0.63	2.0
K.S.	0.63	0.6	0.39	0.3	0.30	0.2	0.42	0.8	0.30	0.7	0.46	0.4
B.G.	0.32	1.7	0	0	NOT DONE		0.97	0.6	1.02	1.2	0.78	1.3
S.H. (NORMAL)	0.13	0.6	0	0	NOT DONE		0.24	0.2	0.13	0.3	0.13	0.6

NOTE:
THE AMPLITUDE OF THE SACCADIC (AMP) IS GIVEN IN DEGREES PER SACCADIC. THE FREQUENCY OF SACCADIC (RATE) IS GIVEN IN SACCADIC PER SECOND.

FOR SUBJECTS G.W. AND K.S. PERSISTENCE READING WERE TAKEN DIRECTLY AFTER SACCADIC BIOFEEDBACK AS WELL AS AFTER THE ENTIRE SESSION (ABOVE RIGHT). PERSISTENCE DIRECTLY AFTER SACCADIC BIOFEEDBACK FOR THESE TWO SUBJECTS IS AS FOLLOWS:

G.W. AMP = 0.60 RATE = 1.0

K.S. AMP = 0 RATE = 0

Table 1
Saccadic
Data

SUBJECT	AMBLYOPIC STEADY FIXATION	AUDITORY SACCADIC FEEDBACK	AUDITORY POSITION FEEDBACK	VISUAL POSITION FEEDBACK	AUDI. SACC. & VIS. POS. FEEDBACK	PERSISTENCE
G.W.	DX=NASAL RATE=0.50	DX=TEMP. RATE=0.12 (BOTH V)	NO DRIFT	NO DRIFT	DX=NASAL	NO DRIFT
B.K.	DX=TEMP. RATE=0.22	DX=V RATE=LOW	DX=V RATE=LOW	HIGHLY V. NOT DONE IN RATE AND DX		HIGHLY V. IN RATE & DX DURATION SHORT, BETWEEN $\frac{1}{2}$ TO 1SEC.; RATE UP TO 0.69s
M.O.	DX=NASAL RATE=0.30	NO DRIFT	NOT DONE	NO DRIFT	NO DRIFT	DX=V ; DURATION USUALLY ABOUT 0.5 SECONDS.
K.S.	DX=NASAL RATE=0 TO 0.27 (V)	DX=NASAL RATE=0 TO 0.49(V)	DX=V RATE=0.30	DX=NASAL RATE=0.30	DX=NASAL RATE=0.22	RATE AND DX ARE VARIABLE: 1. TEMP: 0 TO 0.15 2. NASAL: 0 TO 0.10
B.G.	NO DRIFT	NO DRIFT	NOT DONE	DX=NASAL RATE: 0 TO 0.12	DX=NASAL RATE=0.76	DX=NASAL; RATE VARIABLE: 0 TO 0.72; DURATION=1SEC
S.H. (NORMAL)	NO DRIFT	DX=NASAL RATE=0 TO 0.06 DUR=2SEC	NOT DONE	NO DRIFT	NO DRIFT	NO DRIFT

NOTE:

THE FOLLOWING ABBREVIATIONS ARE USED IN THE ABOVE TABLE: DX = DIRECTION OF DRIFT;
TEMP = TEMPORAL; DUR = DURATION OF DRIFTS IN SECONDS; V = VARIABLE;
THE RATE OF DRIFTS IS GIVEN IN DEGREES PER SECOND.

Subject	Best Aided Acuity	RX	Fixation of Ambly- opic Eye	Phoria or Tropia	Correspondence
G.W.	OD 20/15 OS 20/40	+4.25 sphere +3.75 sphere	nasal/sup. e.f. 6-8° unsteady	10 ^Δ left SOJ	UARC
B.K.	OD 20/20 OS 20/15	-7.00-2.50x180 -6.00-2.50x180	central unsteady	12 ^Δ SOJ @ F 25 ^Δ SOJ @ N	HARC (troposcope) NRC (Bielschowsky)
M.O.	OD 20/15 OS 20/40	+0.50-0.75x155 +0.50-0.75x20	nasal e.f. unsteady	4 ^Δ SOP @ N ortho @ F	NRC
K.S.	OD 20/20 OS 20/60	+1.50-0.25x180 +1.50-0.50x178	nasal e.f. unsteady	10 ^Δ left SOJ	ARC
B.G.	OD 20/30 OS 20/15	-1.25-1.25x175 -0.50-1.25x150	central unsteady	4 ^Δ XOP @ N 5 ^Δ XOP @ F	NRC
S.H. (normal)	OD 20/15 OS 20/15	-1.75-0.25x08 -2.00-0.12x176	central steady	2 ^Δ XOP @ F 4 ^Δ XOP @ N	NRC

Note:

Abbreviations used in the above table are as follows: sup.=superior;
e.f.=eccentric fixation; SOJ=esotrope; XOP=exophoria; SOP=esophoria;
N=near; F=far; UARC=Unharmonious ARC; HARC=Harmonious ARC; ARC=Abnormal
Retinal Correspondence.

SUBJECT: G.W.



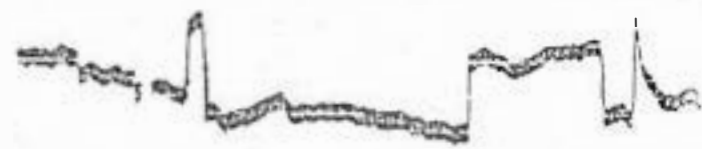
AMBLYOPIC STEADY FIXATION
(DRIFT SEGMENT)



AMBLYOPIC STEADY FIXATION
(SACCADIC SEGMENT)



AUDITORY SACCADIC BIOFEEDBACK



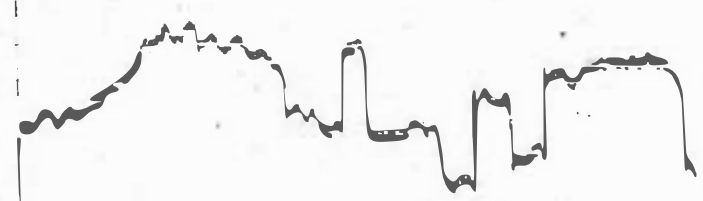
AUDITORY POSITION BIOFEEDBACK



VISUAL POSITION BIOFEEDBACK



AUDITORY SACCADIC AND
VISUAL POSITION BIOFEEDBACK

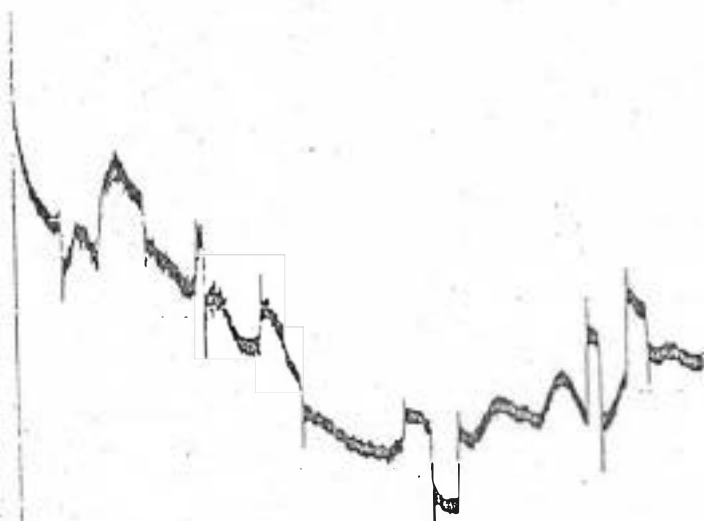


PERSISTENCE DIRECTLY AFTER
AUDITORY SACCADIC BIOFEEDBACK

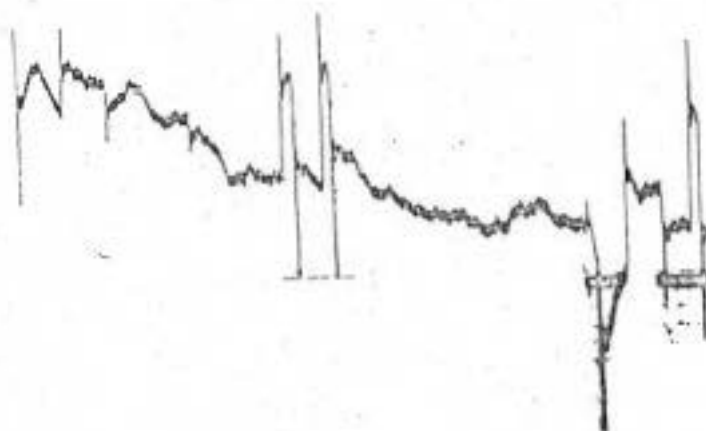


PERSISTENCE

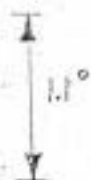
SUBJECT: B.K.



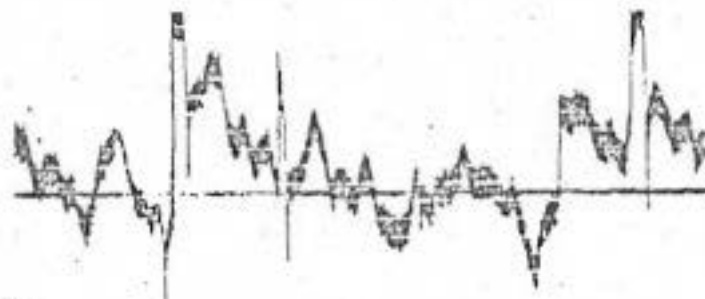
AMBLYOPIC STEADY FIXATION



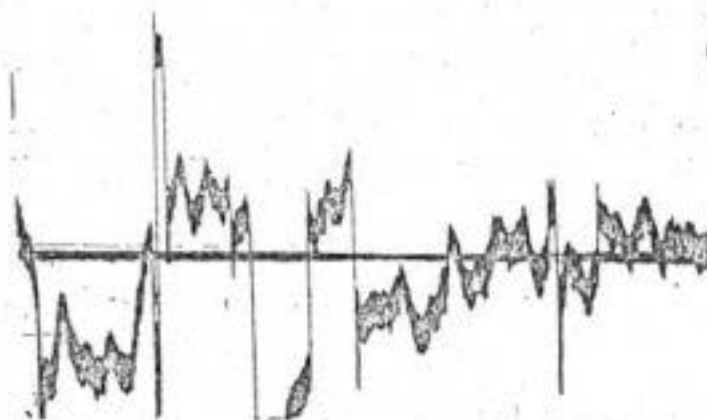
AUDITORY SACCADIC BIOFEEDBACK



AUDITORY POSITION BIOFEEDBACK

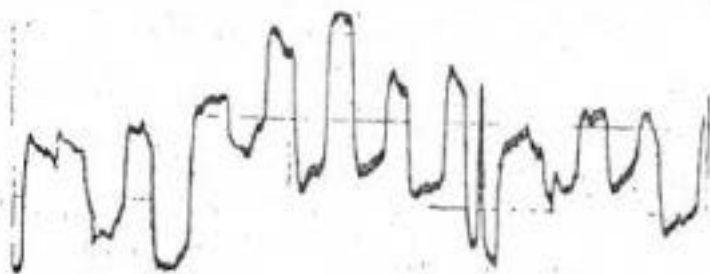


VISUAL POSITION BIOFEEDBACK



PERSISTENCE

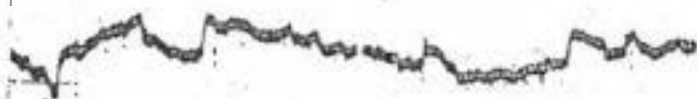
SUBJECT: M.O.



AMBLYOPIC STEADY FIXATION



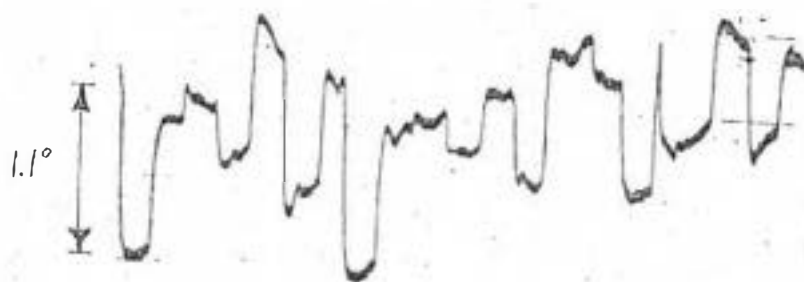
AUDITORY SACCADIC BIOFEEDBACK



VISUAL POSITION BIOFEEDBACK

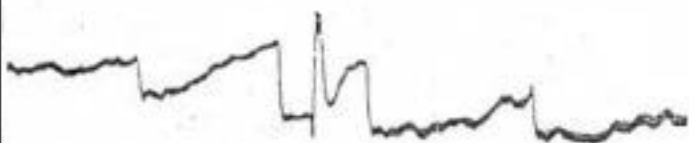


AUDITORY SACCADIC AND
VISUAL POSITION BIOFEEDBACK



PERSISTENCE

SUBJECT: K.S.



AMBLYOPIC STEADY FIXATION



AUDITORY SACCADIC BIOFEEDBACK



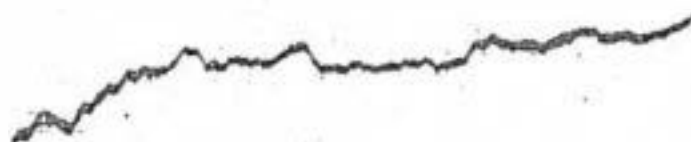
AUDITORY POSITION BIOFEEDBACK



VISUAL POSITION BIOFEEDBACK



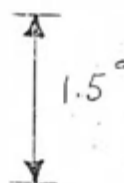
AUDITORY SACCADIC AND
VISUAL POSITION BIOFEEDBACK



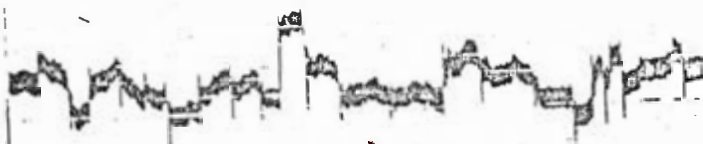
PERSISTENCE DIRECTLY AFTER
AUDITORY SACCADIC BIOFEEDBACK



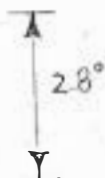
PERSISTENCE



SUBJECT: B.G.



AMBLYOPIC STEADY FIXATION



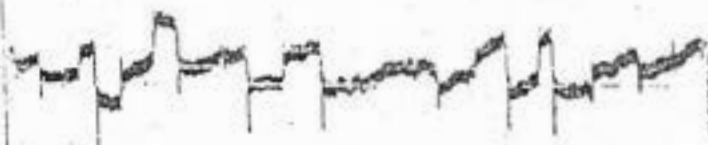
AUDITORY SACCADIC BIOFEEDBACK



VISUAL POSITION BIOFEEDBACK

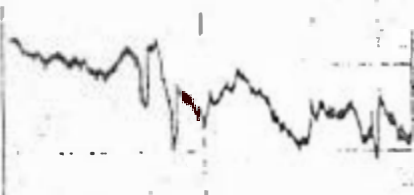


AUDITORY SACCADIC AND
VISUAL POSITION BIOFEEDBACK



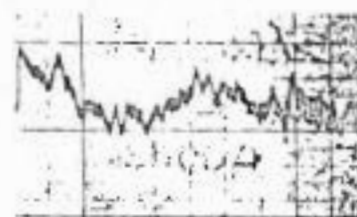
PERSISTENCE

SUBJECT: S.H.

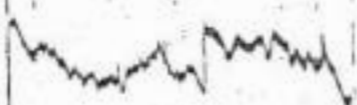


NORMAL STEADY FIXATION

0.53°



AUDITORY SACCADIC BIOFEEDBACK



VISUAL POSITION BIOFEEDBACK

NOTE AND TAKE INTO ACCOUNT THE
TIME SCALE DIFFERENCES (VERTICAL
LINE SPACINGS) FOR THIS SUBJECT.



AUDITORY SACCADIC AND
VISUAL POSITION BIOFEEDBACK



PERSISTENCE

Conclusions

We made the following observations during the sessions with the subjects, and we made the following deductions from the data collected:

1. Fixation stability varied within subjects on a given task as a function of time.
2. Fixation characteristics could be modified by various forms of biofeedback.
3. The effectiveness of the biofeedback varied between subjects (eg. some subjects liked auditory; some subjects liked visual; some subjects liked both; some subjects did not respond well to either.)
4. Not all forms of biofeedback were equally effective for each subject, but there were some consistencies: saccadic auditory biofeedback and position visual biofeedback were generally very effective.
5. The rate of learning or delay of first modification of behavior differed for various forms of biofeedback. Visual is fastest. (Perhaps visual is fastest because the subject is accustomed to responding to a visual stimulus rather than an auditory one.)
6. A number of the subjects showed fixation improvement following biofeedback, however a control should be run to determine the influence of placebo on biofeedback.
7. Subjective reports by the subjects tell us that eccentric fixation is still present after saccades have been suppressed. It is necessary to correct the position error of eccentric fixation, preferably

with visual biofeedback, and enhance visual acuity.

8. All subjects report fading of the fixation target (Troxler's phenomenon) with the elimination of saccades in steady fixation.